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Mitigating Impact of Blackhole Attack in MANET

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***Abstract*— Mobile Ad Hoc Network (MANET) is one kind of new wireless network structures which is also known as infrastructure less network. Unlike devices in traditional wireless LAN solution, all nodes are movable and the topology of the network is changing dynamically in an Ad Hoc Network, which brings great challenges to the security of Mobile Ad Hoc Networks. MANET is particularly vulnerable to various types of security attacks due to its fundamental characteristics e.g. the lack of centralized monitoring, dynamic network topology, open medium, autonomous terminal and management. As a result, attackers can take advantage of flaws in routing protocols to carry out various attacks. The black hole attack is one of such security issue in MANET. It could disturb the routing protocol and bring about huge damage to the network's topology. In this attack, a malicious node gives false information of having shortest route to the destination node so as to get all data packets and drops it. In this paper, we propose an algorithm which mitigates the impact of black hole attack in AODV routing.**

***Index Terms*— AODV, Blackhole attack, Anti Near Blackhole-AODV (ANB-AODV), Anti Far Blackhole-AODV (AFB-AODV)**

I. INTRODUCTION

Mobile Ad Hoc Network (MANET) is a collection of infrastructure less nodes that cooperates with each other to make temporary network. It consists of a collection of wireless mobile nodes that have capability to communicate with each other without the use of network infrastructure or any centralized administration. Also security is important to provide protected communication between nodes in a potentially hostile environment. Although security has long been an active research topic in wireless networks, the unique characteristics of MANETs present a new set of challenges to security design. These challenges include shared wireless medium, highly dynamic network topology, open network architecture and stringent resource constraints. Consequently, the existing security solutions for wired networks do not directly apply to the MANET domain. Routing protocol in MANET is divided into two main categories, one is proactive and other is reactive. In proactive routing protocols, routing information of nodes is exchanged, periodically, such as DSDV. In on-demand routing protocols, route is established and nodes exchange routing information when needed such as AODV [1]. Furthermore, some ad-hoc routing protocols are a combination of above categories which are called as hybrid routing protocols.

II. OVERVIEW OF AODV

The Ad Hoc On-Demand Distance Vector (AODV) is routing protocol for mobile adhoc network and is an

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adaptation of the DSDV protocol used in wired network for dynamic link conditions [1][2][3].The AODV is based on-demand approach for finding route i.e. a route is established only when it is required by a source node for sending data packets and hence it is also known as reactive protocol. In order to identify the most recent path for communication, it uses high destination sequence numbers. Every node in an Ad-hoc network keeps a routing table, in which there is information about the path or route to a particular destination. Whenever a node wants to send data packet, it first checks its routing table to check whether a route to the destination is already exist. If so, it uses that path to send the packets to the destination. If a path is not available or the previously entered path is inactivated, then the node starts a route discovery process. In route discovery process before the actual transmission of data packets, RREQ (Route REQuest) packet is broadcasted by the source node. Every node in the network that receives the RREQ packet first checks whether it is the destination for that packet and if so, it sends back an RREP (Route REPly) packet via reverse path. If it is not the destination, then it checks with its routing table to determine whether it has fresh route to the destination. If not, it broadcast RREQ packet to all its neighbours. If its routing table does contain an entry to the destination, then the comparison is done between destination sequence numbers in its routing table with the destination sequence number contained in the RREQ packet. This Destination Sequence number is the sequence number of the last sent packet from the destination to the source. If the destination sequence number present in the routing table is lesser than or equal to the one contained in the RREP packet, then the node update its routing table. If the destination sequence number in the routing table is higher than the destination sequence number contained in the RREP packet, it means that the route is a fresh route and packets can be sent via this route. This intermediate node then sends a RREP packet to the node through which it received the RREQ packet. The RREP packet is sent back to the source node through the reverse route. The source node then updates its routing table and sends its packet through this route. During the communication, if any node identifies a link breakage it sends a RERR (Route ERRor) packet to all other nodes that uses this link for their communication to other nodes. Since there is no security mechanism in AODV protocol, malicious nodes can perform many attacks in network by not following according to AODV rules. A malicious node can carry out many attacks against AODV like blackhole, wormhole, sinkhole, sybil attack etc.

III. BLACKHOLE ATTACK

A Black Hole attack [4] is a denial of service type of attack where a malicious node gives false information of having shortest route to the destination in order to get all the data packets and drop it. In blackhole attack, once malicious node receives request (RREQ) packet, it sends back reply (RREP) packet which contain very high destination sequence due to which the source node consider it as a fresh route and start sending data packet via the path from which reply packet came. In the following Fig. 1, imagine a malicious node M. When node S broadcasts a RREQ packet in order to communicate with destination node, then other neighbour node receives it. Node M, being a malicious node, does not check up with its routing table for the requested route to node D. Hence, it immediately sends back a RREP packet, claiming of having shortest path to the destination. Node S receives the RREP from M immediately and assumes that the route through M is the shortest route as well as fresh route and thereby starts sending data packets to the destination through this path. When the node S sends data packet to M, it absorbs all the data and drop the packets thus behaving like a Black hole.

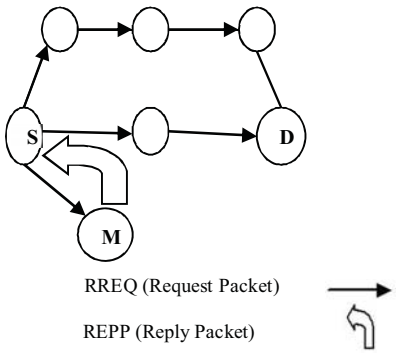

Figure 1. Black hole Attack in AODV

IV. Related Work

H. Deng, W. Li, and D.P. Agrawal [4] proposed a protocol that needs the intermediate nodes to send RREP message along with next hop information. Once the source node gets this information, it sends a request (RREQ) packet to following hop to verify that the target node (i.e. the node that simply sent back the RREP packet) has a route to the intermediate node and to the destination. Once next hop receives an Further Request, it sends a Further Reply which has the check result to the source node. Based on information contained in reply packet the source node checks the validity of the route. In this protocol, the RREP packet is modified to contain the knowledge regarding next hop. On receiving RREP, the source node send RREQ to the node specified as next hop within the received RREP.B. Sun, Y. Guan, J. Chen and U. Pooch [5] use AODV as their routing protocol and simulation is done in ns2 simulator. The detection scheme used neighbourhood-based method to detect the black hole attack and then present a routing recovery protocol to build the true path to the destination. Based on the information about neighbour set, a solution is designed to deal with the black hole attack, which comprised of two parts. The first one is detection and second is response. In detection part, there are two steps. In first step there is collection of information about neighbour set and in second step it determines whether there exists a black hole attack. In Response mechanism, source node sends to destination node a modify-Route-Entry (MRE) control packet to form a correct path through modifying the route entries of the intermediate nodes from source to destination.S. Ramaswamy, H. Furong, M. Sreekantaradhya, J. Dixon and K. Nygard presented an algorithm in [6] which claims to prevent the cooperative black hole attacks in ad-hoc network. In this algorithm each node maintains an additional Data Routing Information (DRI) table. Moreover, the solution takes more time to complete in the case when the network in not under the attack. This algorithm is based on a trust relationship between the nodes, and hence it cannot able to tackle gray hole attacks.M. Al-Shurman, S-M. Yoo and S. Park [7] proposed two different approaches to solve the black hole attack. In the first solution the sender node must verify the genuineness of the node that initiates the RREP packet by utilizing the redundancy of the network. The main idea of this approach is to find more than one path for the destination. The disadvantage of this technique is the time delay. In the second approach it needs to store the sequence number of last sent packet and the sequence number of last received packet in the table and it is updated only when any packet is transmitted or arrived. When node receives reply from another node it checks the sequence number of the last sent and received packet. If there exists any mismatching then an alarm indicates the existence of a black hole node. This solution has no overhead and is faster as well as more reliable. Tamilselvan and Dr.V. Sankaranarayanan [8] proposed a solution to prevent blackhole attack in which the requesting node does not send data packets immediately after receiving first reply from neighbouring node rather it waits for other replies with next hop details from the other neighboring nodes for some duration of time value. After expiry of time value, it then first checks in the Collect Route Reply Table for the presence of any repeated next-hop-node. If there is any repeated next-hop-node in the reply paths, it assumes that the paths are safe or the chance of malicious paths is reduced. H.Weerasinghe and H. Fu [9] proposed a solution in which the intermediate node sends reply (RREP) packet which contains the knowledge or data about the next hop to destination when it receives a request (RREQ) packet. After that the source node sends a further request (FREQ) packet to next hop of replied node and asks regarding replied node and route to the destination. Through this technique, it is able to determine the trustiness of the replied node only if the next hop is reliable. However, this methodology is not able to prevent cooperative black hole attack on MANETs. L. Tamilselvan and Dr. V.Sankaranarayanan [10] also proposed an enhanced AODV routing protocol, known as PCBHA (Prevention of a Co-operative Black Hole Attack) for prevention of cooperative black hole attack. In this technique, it provides every node with a default fidelity level, and once broadcasting of RREQ packet is done, a source node waits for RREPs packet coming from the other neighbouring nodes, and then it chooses a neighbouring node of a higher fidelity level that exceeds the threshold value for passing the data packets. After receiving data packet, the destination node sends ACK message and upon receipt of an ACK response, the source node may add 1 to the fidelity level of the neighbouring node. If no ACK response is received, 1 is deducted from the fidelity level that indicates a potential malicious node on this route due to which data packets are dropped before reaching the destination node. M. Medadian , A. Mebadi, E. Shahri [11] have proposed an approach to mitigate the impact of black hole attack through the judgment process by using honesty of nodes. The honesty of any node is derived from the opinions of neighbor nodes of a node in a network. A node should show its honesty in order to transfer the data packets. If a node is the first receiver of a RREP packet, it forwards packets to source and initiates judgment process on about replier. The judgment process is dependent upon the opinion of network's nodes regarding replier. These neighbors are

requested to send their opinion about a node. When a node gathers all opinions of neighbors, it makes decision whether the replier is a malicious node or not based on number rules. N. Mistry, D.C. Jinwala and M. Zaveri [12] proposed a solution for analyzing and improving the security of AODV routing protocol against black hole Attack. The approach basically modifies the working mechanism of source node only by using an additional function named as Pre_ReceiveReply. A table Cmg_RREP_Tab, a variable Mali_node and a new timer MOS_WAIT_TIME are also added to the original standard AODV protocol. In the proposed solution, the source node waits for MOS_WAIT_TIME after receiving the first RREP and it collects all the replies within the Cmg_RREP_Tab table til MOS_WAIT_TIME. In this technique the value of MOS_WAIT_TIME is considered to be half the value of RREP_WAIT_TIME. Now, the source node will check the stored replies and will discard the reply having high destination sequence number. The node is considered as malicious node which has sent this RREP packet with high destination sequence number..M.Y. Su [13] proposed the mechanism to detect and separate malicious nodes, which selectively perform black hole attacks by deploying IDSs in MANETs (mobile ad hoc networks). All IDS nodes perform an Anti-Black hole Mechanism (ABM), in which it estimates the suspicious value of a node, according to the amount of abnormal difference between RREQs and RREPs transmitted from the node. With the main condition that intermediate nodes are forbidden to reply to RREQs, if an intermediate node that has never broadcasts a RREQ for a specific route and is also not a destination, forwards a RREP for the route then its suspicious value will be augmented by 1 in the nearby IDS's SN (suspicious node) table. When the suspicious value of a node exceeds a threshold value, a block message is broadcasted by the detected IDS to all nodes on the network in order to cooperatively isolate the suspicious node. K. Liu and J. Deng [14] proposed a 2ACK scheme to detect and mitigate the effect of such routing misbehaviour. The 2ACK technique is based on a simple 2-hop acknowledgment packet that is sent back by the receiver of the next-hop link. When compared with other techniques to overcome the problem, such as the overhearing technique, the 2ACK scheme overcomes several problems including ambiguous collisions limited transmission powers and receiver collisions.S. Gurung ,Dr. K. K. Saluja and A. Kumar[15] proposed an approach for detection of blackhole attack in manet.The proposed method is based on conformation acknowledgment request (CARREQ) to check whether the destination has received dummy packet or not. In this technique, Reply table and Blacklist table are required for blackhole node detection. In this approach, the source node sends conformation acknowledgment request (CARREQ) via other path to destination node and if the destination sends back conformation acknowledgment reply (CARREP) then the intermediate node to which the source node initially send the dummy packet is trusted node otherwise it is considered as a malicious node. The drawback of this solution is time delay.In Table. I, the drawbacks of techniques have been highlighted [15][16].

TABLE I. DRAWBACKS OF TECHNIQUES

S.No.	Methodology proposed By	Attack	Drawbacks
1	H. Deng , W. Li, and D.P. Agrawal [4]	Single Blackhole	Cannot prevent cooperative blackhole attack. Routing Overhead.
2	B. Sun, Y. Guan, J. Chen and U. Pooch [5]	Single Blackhole	Becomes useless when the attacker agrees to forge the fake reply packets.
3	S. Ramaswamy, H. Furong, M. Sreekantaradhya, J. Dixon and K. Nygard [6]	Cooperative Blackhole	Cannot tackle grayhole attack.
4	M. Al-Shurman , S. Yoo and S.Park [7]	Single Blackhole	Time Delay. Attacker can listen to the channel and update the tables for last sequence number.
5	L. Tamilselvan and Dr.V. Sankaranarayanan [8]	Single Blackhole	Time Delay. Finding repeated next hop is additional overhead.
6	H. Weerasinghe, H. Fu [9]	Cooperative Blackhole	5-8% more communication overhead of route request.
7	L. Tamilselvan and Dr.V. Sankaranarayanan [10]	Cooperative Blackhole	Time Delay.
8	M. Medadian , A. Mebadi, E. Shahri [11]	Cooperative Blackhole	Opinion of neighbour may not be always correct.
9	N. Mistry , D.C. Jinwala and M. Zaveri [12]	Single Blackhole	Time Delay. Failed to detect cooperative blackhole attack.
10	M.Y. Su [13]	Multiple Blackhole	Time Delay.
11	S. Gurung ,Dr. K. K. Saluja and A. Kumar[15]	Single Blackhole	Time Delay

V. PROPOSED METHODOLOGY

In this section, we propose a solution to mitigate the impact of black hole attack in the network. Following is the diagram showing blackhole attack.

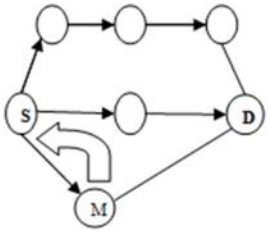

Figure 2. M and D path

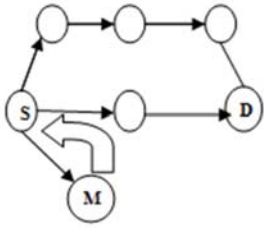

Figure 3. No M and D path

RREQ (Request Packet) →

REPP (Reply Packet) ↩

A. Matrix Representation

TABLE II. TRUTH TABLE OF BLACKHOLE NODE

Figure No.	Shortest route to Destination	Malicious Node	Packet Drop
2	T	T	T
3	F	T	T

From the above Table. II, it is shown that if there is path between malicious node and destination as given in Fig. 2, which is of shortest path then the malicious node will drop the packet and if there is no path between them as depicted in Fig. 3 and it gives false statement of having shortest path to destination even then also it will drop the data packets.

B. ANB-AODV: Anti Near Blackhole-AODV

In order to mitigate the impact of blackhole attack in manet, AODV protocol has been slightly changed. In this approach, when sender broadcast the RREQ packet, it will wait for reply. The source node will get first reply from malicious node provided the malicious node is near to source node as shown in Fig. 4 and acquire the data packet and it will not forward the packet to the destination. In proposed methodology i.e. ANB-AODV (Anti Near Blackhole-AODV), the source node will accept the first reply coming from malicious node and start sending data packets. But after some time when the second reply comes from original destination, it will accept the second reply and start sending via this alternative path as shown in Fig. 5.

Algorithm for ANB-AODV

1. If Reply table is NULL
2. Set count: =0
3. Insert Destination node
4. Else
5. Set count:=count+1
6. Update Route Table

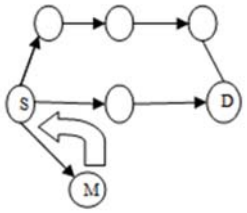

Figure 4. Accepting First Reply

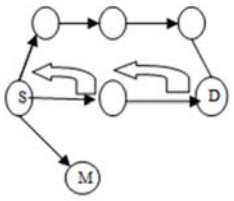

Figure 5. Accepting second reply

C. AFB-AODV: Anti Far Blackhole-AODV

In order to mitigate the impact of blackhole attack in MANET, AODV protocol has been slightly changed. In this approach, when sender broadcast the RREQ packet, it will wait for reply. The source node will get first reply from destination original node provided the destination node is near to source node and malicious node is far away from source node as shown in Fig. 6. In proposed methodology i.e. AFB-AODV (Anti Far Blackhole-AODV), the source node will accept the first reply coming from original destination node and start sending data packets. But after some time when the second reply comes from malicious node, it will reject the second reply as shown in Fig. 7.

Algorithm for AFB-AODV

1. If Reply table is NULL
2. Set count =0
3. Insert Destination node
4. Update Route Table
5. Else
6. Set count:=count+1 and Drop Reply

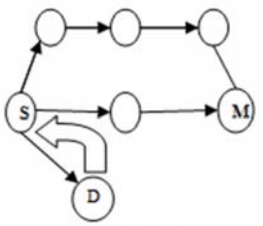

Figure 6. Accepting First Reply

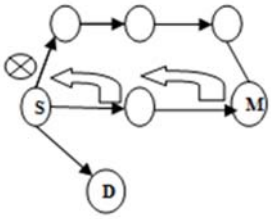

Figure 7. Rejecting second reply

VI. Simulation Environment And Result

A simulation model was developed using NS-2 (version 2.34) where the evaluation was done by analyzing the performance of network under without blackhole attack and with blackhole attack. Two scenarios are taken one is static in which no node is mobile and other one is mobility in which Random Waypoint mobility model is used.

A. Static Scenario

1. ANB-AODV

In this scenario, no node is movable that is these nodes are static and AODV routing protocol is used. When there is no malicious node then source node gets reply from destination node and starts transferring data packet thereby having packet delivery rato percentage upto 100 %. But when malicious node is present in the network it gives first reply to source node when source node broadcast the route request. Thus the source node will accept the first reply coming from malicious node thereby starts transferring data packets to this node due to which there is decrease in packet delivery ratio in AODV routing protocol. When ANB-AODV routing protocol is used it will reject the first reply coming from blackhole node and accept the second reply coming from original destination node thereby increasing the packet delivery ratio as shown in Fig. 8.

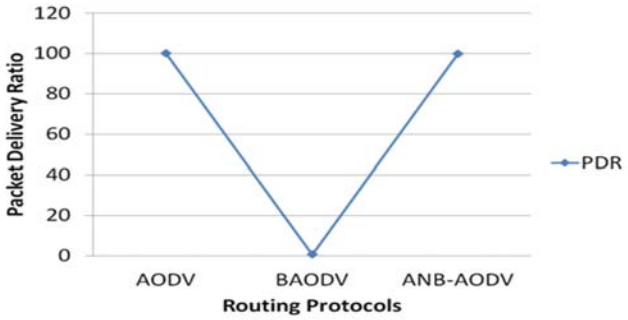

Figure 8. PDR %age in presence of Blackhole Attack

2. AFB-AODV

When there is no malicious node then source node gets reply from destination node and starts transferring data packet thereby having packet delivery ratio percentage upto 100 %. But when malicious node is present in the network, the source node gets second reply from malicious node after getting first reply from original destination node. Thus the source node will accept the second reply coming from original destination node thereby starts transferring data packets to this node due to which there is decrease in packet delivery ratio in AODV routing protocol. When AFB-AODV routing protocol is used it will reject the second reply coming from blackhole node and accept the first reply coming from original destination node thereby increasing the packet delivery ratio as shown in Fig. 9.

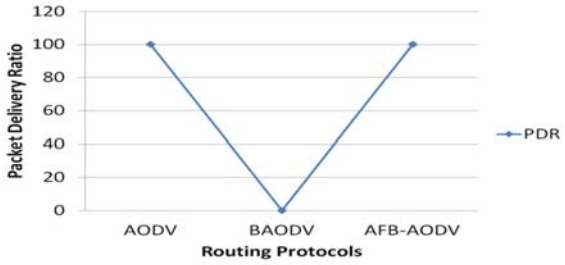

Figure 9. PDR %age in presence of Blackhole Attack

B. Mobility Scenario

In this scenario all nodes are movable. Fig. 10 is showing network without blackhole attack. The mobility model used in the network is Random Waypoint Mobility model. In mobility case, in each scenario the nodes are randomly positioned and moves with different speed as depicted Fig. 11.

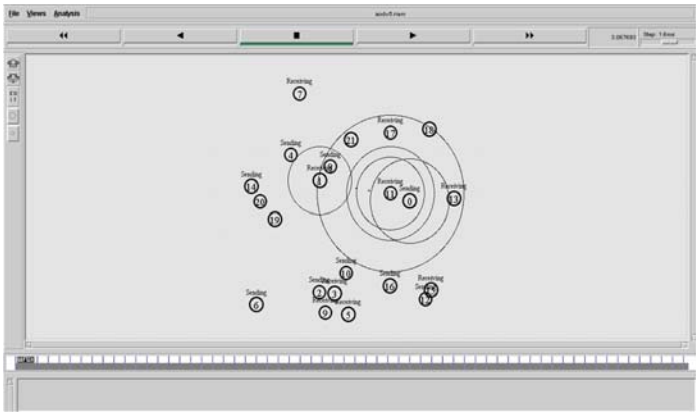

Figure 10. Network without Blackhole Attack

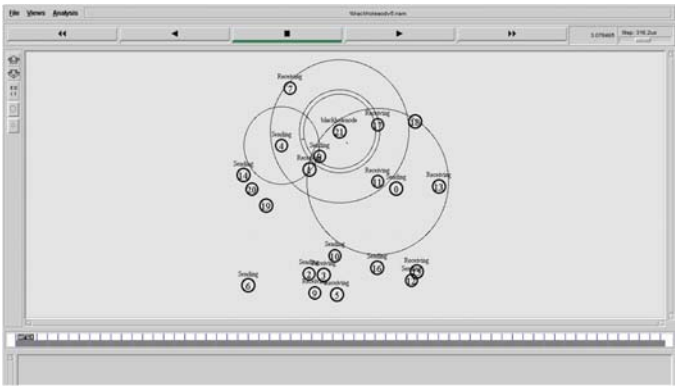

Figure 11. Network with Blackhole Attack

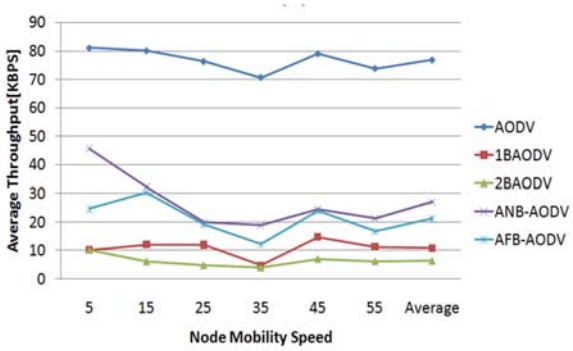

Figure 12. Average Throughput in presence of Blackhole Attack

From Fig. 12, it is clear that when there is no attack in network, the average throughput is high but when there is blackhole attack in the network this throughput goes down because of packet drop by blackhole node. The average throughput is very low in case of two blackhole node in the network as compared to one blackhole node which shows that increasing blackhole node results in decreasing the average throughput of the network. When ANB-AODV or AFB-AODV is used there is increase in the average throughput which improves the performance of network.

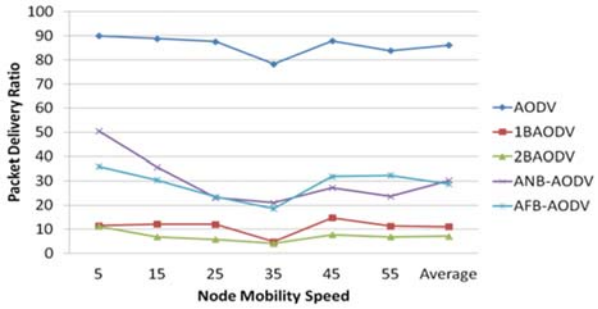

Figure 13. PDR %age in presence of Blackhole Attack

From Fig. 13, it is clear that when there is no attack in network, the packet delivery ratio is high but when there is blackhole attack in the network this packet delivery ratio goes down low due to packet dropping by malicious node. The packet delivery ratio is very low in case of two blackhole node in the network as compared to one blackhole node which shows that increasing blackhole node results in decreasing the packet delivery ratio of the network. When ANB-AODV and AFB-AODV protocol is used, there is increase in the packet delivery ratio thereby improving the performance of network.

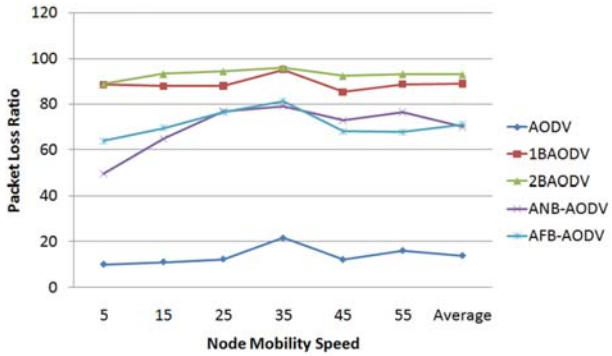

Figure 14. Packet Loss %age in presence of Blackhole

From Fig. 14, it is clear that when there is no attack in network, the packet loss is low but when there is blackhole attack in the network this packet loss goes up because of packet dropping by malicious node. The

packet loss ratio is very high in case of two blackhole node in the network as compared to one blackhole node which shows that increasing blackhole node results in increasing the packet loss of the network. When ANB-AODV and AFB-AODV protocol is used then there is decrease in the packet loss thus improving the performance of network.

VII. Conclusions

Security is important in wireless Mobile Adhoc networks as they are prone to various network threats and vulnerable to various kinds of attacks like sinkhole, wormhole, rushing attack, Black Hole attack and so on. The performance of the proposed approach under Black Hole attack has been compared with AODV under Black Hole attack. The simulation results show that the proposed approach is effective in improving the performance of the network. As a future work, we intend to propose new algorithm for the detection and prevention of blackhole attack.

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